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Os incae: variation in frequency in major human population groups

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ABSTRACT

The variation in frequency of the Inca bone was examined in major human populations around the world. The New World populations have generally high frequencies of the Inca bone, whereas lower frequencies occur in northeast Asians and Australians. Tibetan/Nepalese and Assam/Sikkim populations in northeast India have more Inca bones than do neighbouring populations. Among modern populations originally derived from eastern Asian population stock, the frequencies are highest in some of the marginal isolated groups. In Central and West Asia as well as in Europe, frequency of the Inca bone is relatively low. The incidence of the complete Inca bone is, moreover, very low in the western hemisphere of the Old World except for Subsaharan Africa. Subsaharan Africans show as a whole a second peak in the occurrence of the Inca bone. Geographical and ethnographical patterns of the frequency variation of the Inca bone found in this study indicate that the possible genetic background for the occurrence of this bone cannot be completely excluded. Relatively high frequencies of the Inca bone in Subsaharan Africans indicate that this trait is not a uniquely eastern Asian regional character.

Key words: Osteology; anthropology; interparietal bone; occipital squama; geographical variation.

INTRODUCTION

The squamous portion of the occipital bone consisting of the interparietal part is sometimes divided by a transverse suture in the position of the highest nuchal line. The Inca bone, the part above this transverse suture, was first described by M. E. Rivero and S. J. Tschudy in 1851 in Peruvian crania (Oetteking, 1930; Matrin & Saller, 1959; Ossenberg, 1969). The same variation is also known as Os interparietale (Le Double, 1903).

In addition to the transverse suture at the highest nuchal line, sometimes one or more longitudinal or additional transverse sutures exist subdividing the Inca bone. These lead to bipartite, tripartite or multipartite Inca bones (Hauser & De Stefano, 1989). According to Kadanoff & Mutafov (1968), when the transverse suture is incomplete and occurs in combination with one or more longitudinal sutures limiting an area corresponding to a part of a partitioned Inca bone, the condition is called a partial Inca bone (Hauser & De Stefano, 1989).

With regard to the frequency distribution of the Inca bone in recent human populations, this has been reported by several investigators: in Native Americans by Oetteking (1930) and Ossenberg (1969); in Subsaharan Africans by De Villiers (1968) and Saxena et al. (1986); in early modern Japanese by Dodo (1975); in Indian subcontinental populations by Srivastava (1977) and Pal et al. (1984); in Oceanian and Pacific populations by Pietrusewsky (1984); in East/Northeast Asians and New World populations by Dodo & Ishida (1987); and in worldwide populations by Martin & Saller (1959) and Hauser & De Stefano (1989). Some of these investigators reported the variants of the Inca bone in their examined populations (Oetteking, 1930; De Villiers, 1968; Ossenberg, 1969; Dodo, 1975; Pal et al, 1984) and more detail by Kadanoff & Mutafov (1968).

On the basis of the occurrence of this trait in fossil

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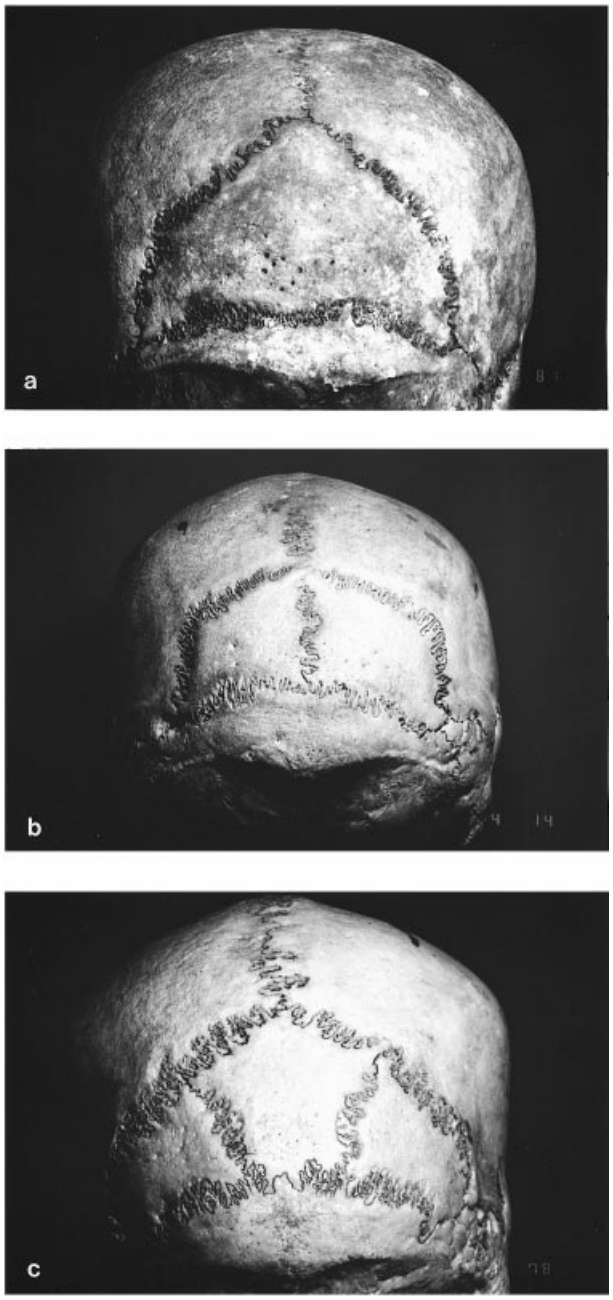

Fig. 1. (*a*) Complete undivided Inca bone (Os incae totum); (*b*) complete symmetric bipartite Inca bone (Os incae bipartitum); (*c*) complete tripartite Inca bone (Os incae tripartitum).

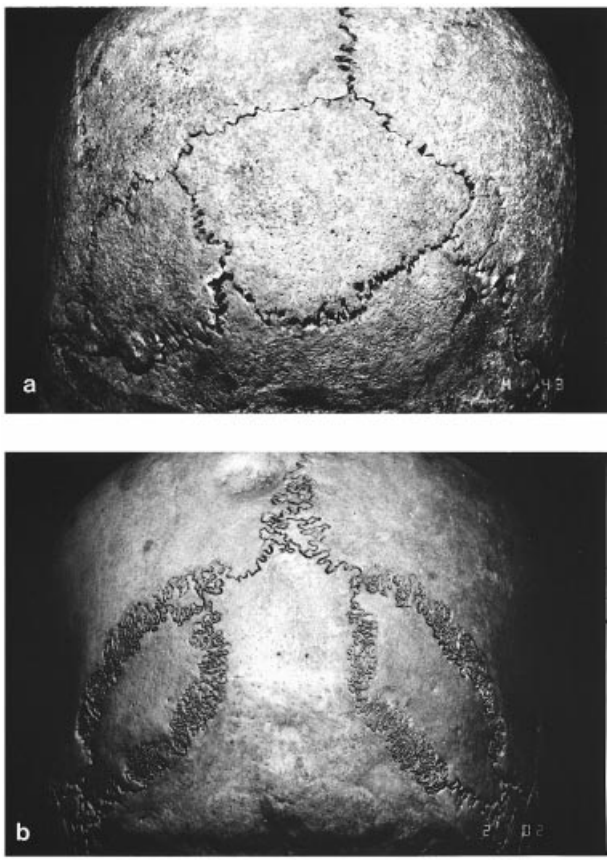

Fig. 2. (*a*) Incomplete asymmetric bipartite Inca bone (Os incae duplex asymmetricum); (*b*) incomplete symmetric bipartite Inca bone (Os incae duplex symmetricum).

hominids such as *Australopithecus*, *Homo erectus*, and early *Homo sapiens* (Weidenreich, 1939, 1943; Dart, 1948; De Villiers, 1968), Ossenberg (1969) pointed out that the mutations transforming the occiput initiated human evolution, and the modern distribution of occipital sutural variations supported this theory. Wu & Wu (1985) reported that the frequent presence of the Inca bone was characteristically a primitive feature found both in Chinese *Homo erectus* and early *Homo sapiens*. Based on such findings together with its frequent occurrence in later fossil and modern populations in China, the Inca bone is regarded as one of the characters that form the morphological basis of the multiregional model for the origin of anatomically modern humans in the eastern Asian region (Weidenreich, 1939, 1943; Wu & Wu, 1985).

Pedigree studies by Togersen (1951) suggested that the Inca bone is inherited as a dominant trait, with approximately 50% penetrance. Strong genetic control of the occurrence of the Inca bone is supported by studies in mice (Deol & Truslove, 1957). On the other hand, a relationship between the incidence and/or distribution of sutural bones in the occipital region and artificial cranial deformation has been suggested (Ossenberg, 1970; Lahr, 1996). These facts suggest that it is difficult to discuss the phylogenetic significance of the Inca bone.

Taking these considerations in mind, the present study is focused first on the presentation of the variations of the Inca bone using uniform criteria in the major human populations of the world. The second purpose of the present study is to elucidate whether this trait is a geographically specific character

Fig. 3. (*a*) Incomplete median Inca bone (Os incae centrale (medianum)); (*b*) incomplete median Inca bone with median suture.

Fig. 4. Incomplete lateral asymmetric Inca bone (Os incae laterale dextrum).

Fig. 5. Incomplete symmetric bipartite Inca bones having contact with each other at midline.

Fig. 6. Pars incoidea squamae occipitalis with multipartite ossicles.

or whether clinal variation exists in recent human populations, in order to address the possible genetic background of this trait.

Variation and embryological background of the Inca bone

The formation and cause of the variation of the occipital suture has long been studied from embryological as well as osteological viewpoints. A good number of investigators such as Oetteking (1930), Martin & Saller (1959), Ossenberg (1969), Hauser & De Stefano (1989) reviewed J. Ranke's schematic representation of the ontogenetic conditions in the occipital squama. However, the concept of the ossification of the upper squamous portion of the occipital bone is somewhat confusing (Mall, 1906; Aichel, 1914; Davida 1914; Srivastava, 1977; Pal et al. 1983; Gopinathan, 1992). According to the embryological studies originally described by Zawisch (1957) and more recently confirmed by Niida et al. (1992), Srivastava (1992), and Matsumura et al. (1993, 1994), the portion of the occipital squama inferior to the superior nuchal line is ossified in cartilage, the superior portion in membrane. They show that there are in total 3 pairs of ossification centres in the membranous part; one pair of the ossification centres (the first primary centres) appears on each side of the midline between the superior and highest nuchal lines, and 2 pairs, medial and lateral (second primary centres) on each side above the highest nuchal line. The formation of the Inca bone is caused by failure of

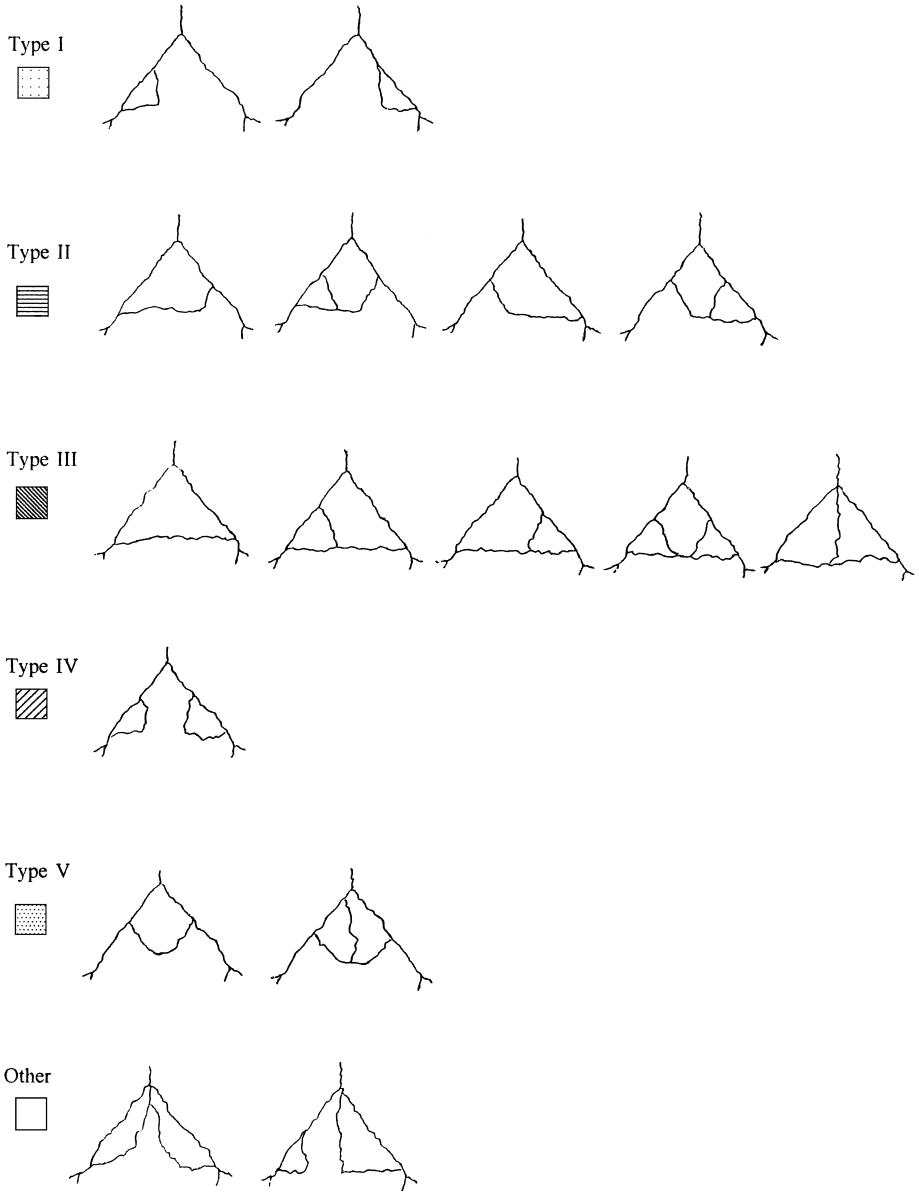

Fig. 7. Six types of Inca bone as classified in the present study. The last type (right side in 'other' type) was observed in individual from the Tagar sample.

fusion of the latter interparietal bones. After the formation of the second interparietal bones, moreover, one or more additional centres for the preinterparietal bone appear at the region of the lambda, forming a triangular region (Matsumura et al. 1994). According to them, it is easy to distinguish the preinterparietal bone from a wormian bone at the lambda in embryological series based on morphological features. Srivastava (1977) and Pal (1987) pointed out, however, that a separate preinterparietal bone should be defined only when it is present behind the lambda within the territory of the membranous part of the occipital bone and separated from the remaining interparietal part by a transverse suture. It should be differentiated from sutural bones at the lambda by its shape and position in adult cranial series.

In the present study, we found various types of sutural variation in the interparietal region. Figure 1*a* shows the complete and undivided Inca bone. The completely symmetric bipartite Inca bone (median suture) and the completely tripartite Inca bone are presented in Figure 1*b*, *c*, respectively. No complete multipartite Inca bone was found in our specimens. Incomplete examples of the Inca bone are given in Figure 2. Figure 2*a* shows the incomplete asymmetric bipartite Inca bone. Incomplete symmetric bipartite Inca bones are illustrated in Figure 2*b*. Variants of incomplete median Inca bones are shown in Figure 3. Figure 4 shows an example of an incomplete lateral

Table 1. *Sex difference in frequency distribution of Inca bone in the large geographical samples*

Sample name	N	Total	Type I	II	III	IV	V	Others
East Asians								
Male	312	0.0417	0.0064	0.0160	0.0064	0.0000	0.0128	0.0000
Female	96	0.0104	0.0000	0.0000	0.0104	0.0000	0.0000	0.0000
Ainu								
Male	206	0.0194	0.0097	0.0000	0.0097	0.0000	0.0000	0.0000
Female	149	0.0268	0.0000	0.0067	0.0067	0.0000	0.0134	0.0000
Mainland SE Asians								
Male	262	0.0305	0.0076	0.0076	0.0076	0.0038	0.0038	0.0000
Female	92	0.0326	0.0000	0.0000	0.0217	0.0000	0.0109	0.0000
Island SE Asians								
Male	484	0.0331	0.0041	0.0021	0.0124	0.0000	0.0145	0.0000
Female	199	0.0352	0.0050	0.0000	0.0101	0.0050	0.0151	0.0000
Northeast Asians								
Male	396	0.0152	0.0025	0.0000	0.0101	0.0000	0.0025	0.0000
Female	244	0.0164	0.0041	0.0000	0.0082	0.0000	0.0041	0.0000
Arctic								
Male	324	0.0556	0.0185	0.0000	0.0154	0.0000	0.0216	0.0000
Female	256	0.0273	0.0117	0.0000	0.0039	0.0000	0.0117	0.0000
North America								
Male	169	0.0651	0.0059	0.0059	0.0237	0.0000	0.0296	0.0000
Female	69	0.0725	0.0000	0.0000	0.0000	0.0000	0.0580	0.0145
Central/South America								
Male	220	0.0682	0.0000	0.0000	0.0364	0.0091	0.0227	0.0000
Female	94	0.0319	0.0000	0.0000	0.0106	0.0000	0.0213	0.0000
Micronesians								
Male	117	0.0171	0.0000	0.0000	0.0085	0.0000	0.0085	0.0000
Female	86	0.0349	0.0000	0.0000	0.0000	0.0000	0.0349	0.0000
Polynesians								
Male	468	0.0235	0.0043	0.0043	0.0106	0.0000	0.0043	0.0000
Female	250	0.0160	0.0000	0.0040	0.0000	0.0000	0.0120	0.0000
Melanesians								
Male	254	0.0551*	0.0236	0.0039	0.0197	0.0000	0.0079	0.0000
Female	160	0.0125	0.0000	0.0000	0.0000	0.0063	0.0063	0.0000
Australians								
Male	170	0.0118	0.0000	0.0000	0.0059	0.0000	0.0059	0.0000
Female	89	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
South Asians								
Male	231	0.0303	0.0000	0.0043	0.0043	0.0000	0.0216	0.0000
Female	81	0.0123	0.0000	0.0000	0.0000	0.0000	0.0123	0.0000
Europeans								
Male	651	0.0184	0.0031	0.0015	0.0031	0.0031	0.0061	0.0015
Female	176	0.0114	0.0057	0.0000	0.0000	0.0000	0.0057	0.0000
UK series								
Male	419	0.0239	0.0095	0.0000	0.0024	0.0000	0.0095	0.0024
Female	220	0.0182	0.0045	0.0000	0.0000	0.0045	0.0091	0.0000
North Africans								
Male	537	0.0317	0.0074	0.0056	0.0056	0.0000	0.0130	0.0000
Female	345	0.0203	0.0058	0.0029	0.0000	0.0000	0.0116	0.0000
Subsaharan Africans								
Male	547	0.0475	0.0018	0.0055	0.0128	0.0000	0.0274	0.0000
Female	295	0.0576	0.0000	0.0102	0.0169	0.0000	0.0305	0.0000

* Significant at 5% level by Fisher's exact probability test.

asymmetric Inca bone. Examples of incomplete symmetric bipartite bones having contact with each other at the midline are given in Figure 5. Figure 6 shows the Pars incoidea squamae occipitalis (Kadanoff & Mutafov, 1968; Hauser & De Stefano, 1989) with multipartite ossicles. It is far from obvious whether these small separated bones originate from preinterparietal bones or sutural bones.

With the possible exception of the examples shown in Figures 5 and 6, all variants of the Inca bone may be explicable in terms of the formation of the squamous portion of the occipital bone.

Table 2. *Frequency distribution of Inca bone in the first classification of the samples*

Sample name	N	Total	Type I	II	III	IV	V	Others
East Asians								
Japanese	157	0.0447	0.0064	0.0191	0.0128	0.0000	0.0064	0.0000
Hokkaido Ainu	254	0.0276	0.0079	0.0039	0.0079	0.0000	0.0079	0.0000
Sakhalin Ainu	102	0.0098	0.0000	0.0000	0.0098	0.0000	0.0000	0.0000
North Chinese	168	0.0060	0.0060	0.0000	0.0000	0.0000	0.0000	0.0000
South Chinese	86	0.0698	0.0000	0.0233	0.0116	0.0000	0.0349	0.0000
Southeast Asians								
Myanmar	187	0.0321	0.0160	0.0107	0.0053	0.0000	0.0000	0.0000
Mainland SE Asians	180	0.0333	0.0000	0.0000	0.0167	0.0056	0.0111	0.0000
Javanese	133	0.0451	0.0000	0.0000	0.0301	0.0000	0.0150	0.0000
Philippines	216	0.0278	0.0000	0.0000	0.0046	0.0000	0.0231	0.0000
Borneans	145	0.0345	0.0138	0.0069	0.0069	0.0000	0.0069	0.0000
Lesser Sunda	67	0.0149	0.0000	0.0000	0.0149	0.0000	0.0000	0.0000
Andamanese/Nicobarese	121	0.0496	0.0083	0.0000	0.0083	0.0083	0.0248	0.0000
Negritos	36	0.0278	0.0000	0.0000	0.0278	0.0000	0.0000	0.0000
Northeast Asians								
Mongolians	182	0.0055	0.0000	0.0000	0.0000	0.0000	0.0055	0.0000
Buryats	151	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Neolithic Baikalians	80	0.0125	0.0000	0.0000	0.0125	0.0000	0.0000	0.0000
Yakuts	65	0.0462	0.0308	0.0000	0.0154	0.0000	0.0000	0.0000
Amur Basin	163	0.0307	0.0000	0.0000	0.0245	0.0000	0.0061	0.0000
Arctic								
Ekvens	110	0.0091	0.0091	0.0000	0.0000	0.0000	0.0000	0.0000
Chukchis	74	0.0270	0.0135	0.0000	0.0135	0.0000	0.0000	0.0000
Aleuts	116	0.0259	0.0086	0.0000	0.0086	0.0000	0.0086	0.0000
Asian Eskimos	130	0.0385	0.0154	0.0000	0.0077	0.0000	0.0154	0.0000
Greenland Eskimos	166	0.0663	0.0241	0.0000	0.0181	0.0000	0.0241	0.0000
New World								
Northwest Coast	94	0.1170	0.0000	0.0106	0.0213	0.0000	0.0851	0.0000
Northwest America	82	0.0366	0.0000	0.0000	0.0122	0.0000	0.0122	0.0122
Northeast America	79	0.0506	0.0127	0.0000	0.0253	0.0000	0.0127	0.0000
Central America	85	0.0471	0.0000	0.0000	0.0353	0.0000	0.0118	0.0000
Peruvians	182	0.0824	0.0000	0.0000	0.0330	0.0110	0.0385	0.0000
Fuegians/Patagonians	66	0.0152	0.0000	0.0000	0.0152	0.0000	0.0000	0.0000
Micronesians								
Mariana	205	0.0244	0.0000	0.0000	0.0049	0.0000	0.0195	0.0000
Polynesians								
Hawaii	156	0.0256	0.0064	0.0064	0.0064	0.0000	0.0064	0.0000
Easter	142	0.0352	0.0000	0.0000	0.0070	0.0000	0.0282	0.0000
Marquesas	104	0.0288	0.0096	0.0000	0.0096	0.0000	0.0096	0.0000
Society	74	0.0270	0.0000	0.0135	0.0135	0.0000	0.0000	0.0000
Maori	174	0.0172	0.0000	0.0057	0.0114	0.0000	0.0000	0.0000
Moriori	95	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Melanesians								
Papua New Guinea	137	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Torres Strait	102	0.0490	0.0294	0.0000	0.0098	0.0000	0.0098	0.0000
North Melanesians	119	0.0840	0.0252	0.0084	0.0336	0.0084	0.0084	0.0000
South Melanesians	94	0.0106	0.0000	0.0000	0.0000	0.0000	0.0106	0.0000
Australian Aborigines								
East Australians	97	0.0103	0.0000	0.0000	0.0000	0.0000	0.0103	0.0000
Southwest Australians	129	0.0077	0.0000	0.0000	0.0077	0.0000	0.0000	0.0000
Central/South Asians								
Tibetan/Nepalese	123	0.0732	0.0000	0.0081	0.0325	0.0000	0.0325	0.0000
Assam/Sikkim	63	0.0635	0.0000	0.0000	0.0317	0.0000	0.0317	0.0000
East India	124	0.0403	0.0000	0.0081	0.0081	0.0000	0.0242	0.0000
South India	180	0.0056	0.0000	0.0000	0.0000	0.0000	0.0056	0.0000
Northwest India	175	0.0514	0.0057	0.0057	0.0228	0.0057	0.0114	0.0000
Kazakhs	77	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
West Asians								
Israel	109	0.0275	0.0183	0.0000	0.0000	0.0000	0.0092	0.0000
Turkey/Cyprus	63	0.0159	0.0159	0.0000	0.0000	0.0000	0.0000	0.0000
Europeans								
Russia	121	0.0248	0.0000	0.0000	0.0083	0.0165	0.0000	0.0000

Table 2. (*cont.*)

Sample name	N	Total	Type I	II	III	IV	V	Others
Afghanistan	42	0.0476	0.0476	0.0000	0.0000	0.0000	0.0000	0.0000
Tagars	142	0.0070	0.0000	0.0000	0.0000	0.0000	0.0000	0.0070
Greek	68	0.0147	0.0000	0.0000	0.0000	0.0000	0.0147	0.0000
Eastern Europe	101	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Italy	202	0.0149	0.0050	0.0050	0.0000	0.0000	0.0000	0.0050
Finland/Ural	79	0.0127	0.0000	0.0000	0.0127	0.0000	0.0000	0.0000
Scandinavia	65	0.0308	0.0000	0.0000	0.0000	0.0000	0.0308	0.0000
Germany	71	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
France	106	0.0189	0.0094	0.0000	0.0000	0.0000	0.0094	0.0000
UK series								
Ensay	114	0.0614	0.0351	0.0000	0.0000	0.0088	0.0175	0.0000
Repton	57	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Poundbury	166	0.0181	0.0000	0.0000	0.0000	0.0000	0.0181	0.0000
Spitalfields-1	249	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Spitalfields-2	102	0.0392	0.0098	0.0000	0.0098	0.0000	0.0098	0.0098
North Africans								
Badari	57	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Naqada	187	0.0267	0.0053	0.0000	0.0053	0.0000	0.0160	0.0000
Gizeh	181	0.0276	0.0110	0.0110	0.0000	0.0000	0.0055	0.0000
Kerma	225	0.0222	0.0000	0.0044	0.0000	0.0000	0.0178	0.0000
Nubia-1	88	0.0568	0.0000	0.0114	0.0227	0.0000	0.0227	0.0000
Nubia-2	136	0.0221	0.0221	0.0000	0.0000	0.0000	0.0000	0.0000
Morocco	32	0.0312	0.0000	0.0000	0.0000	0.0000	0.0313	0.0000
Subsaharan Africans								
Somalia	72	0.0417	0.0000	0.0000	0.0000	0.0000	0.0417	0.0000
West Africa	55	0.1273	0.0000	0.0000	0.0727	0.0000	0.0545	0.0000
Nigeria-1	163	0.0429	0.0061	0.0061	0.0123	0.0000	0.0184	0.0000
Nigeria-2	131	0.0763	0.0000	0.0153	0.0153	0.0000	0.0458	0.0000
Gabon	147	0.0544	0.0000	0.0068	0.0136	0.0000	0.0340	0.0000
Tanzania	98	0.0204	0.0000	0.0000	0.0000	0.0000	0.0204	0.0000
Kenya	148	0.0541	0.0000	0.0135	0.0000	0.0000	0.0405	0.0000
South Africa	133	0.0451	0.0000	0.0000	0.0301	0.0000	0.0150	0.0000
Khoisans	68	0.0147	0.0000	0.0000	0.0147	0.0000	0.0000	0.0000

MATERIALS AND METHODS

Materials

The materials used in the present study are from osteological or ethnographic collections located in museums and universities in United Kingdom, France, Russia, United States and Japan. Brief information about the samples is presented in the Appendix. The materials housed in the museums and universities in Russia and the Smithsonian Institution in the USA, and the Ainu and North Chinese samples at the University of Tokyo were examined by H. I. and others by T. H. The recent Japanese sample housed in Tohoku University was examined both by H. I. and T. H. independently to exclude potential interobserver error.

Considering a potential relationship between the incidence of sutural bones and artificial cranial deformation, we only examined normal skulls in this study.

In the present study, 2 different classifications of the samples are presented. The first is based mainly on countries and tribes, the second on a wide geographical background taking into consideration linguistic and ethnological similarities.

Methods

The usefulness of available data on the Inca bone is to some extent limited because of different criteria and terminology employed by researchers, in particular because of confusion between the Os incae and Os apicis. In the present study, we follow Hauser & De Stefano (1989) and Kadanoff & Mutafov (1986) for criteria and nomenclatures of the variants of the Inca bone.

The variants of the Inca bone classified in this study are presented in Figure 7. With regard to type V variants, it may be difficult to distinguish the incomplete median Inca bone (Os incae centrale (medianum)) from the preinterparietal bone or Os apicis. In the present study, the following 2 criteria are tentatively applied for differentiating the median Inca

bone from the preinterparietal bone: (1) extension of the bone beyond the medial one-third of the lambdoid suture, and (2) a diamond or a pentagonal shape, not a triangular shape.

Individuals having a Pars incoidea squamae occipitalis as shown in Figure 6 were not scored as positive.

Some investigators have pointed out that a higher male incidence is a characteristic of this trait (Martin & Saller, 1959; Berry, 1975). In the present study, sex difference is tested by Fisher's exact probability test and the χ^2 test.

RESULTS

Fisher's exact probability test and the χ^2 test for the large geographical groups (2nd classification) with sufficient male and female sample sizes show that the expression of the Inca bone does not differ significantly between sexes except for the Melanesian sample (Table 1). The Melanesian sample shows significant sex difference in the total incidence of the Inca bone in Fisher's exact probability test. However, the result for the χ^2 test shows that there is no significant difference in the occurrence of each type between sexes. Based on almost no significant sex difference in the occurrence of the Inca bone, the sex-combined incidence for the samples of the first classification is summarised in Table 2. Visual expression of the incidence of the Inca bone in each type is illustrated in Figure 8.

A geographical pattern of Inca bone variation is not particularly obvious but, at the same time, there are some regional variations within each circumscribed geographical area. This trait is relatively uncommon in the western Eurasian and Northeast Asian samples. On the other hand, the New World and the Subsaharan African samples exhibit the Inca bone in relatively high frequencies. The Northwest Coast sample of the New World and the West African sample are the only groups that show frequencies exceeding 10%. The Australian samples are outliers by Pacific standards with frequencies of 1% or less.

Table 3 summarises the sample structure in the second classification. Figure 9 shows the variations in frequency of the Inca bone on the world map. In the Eastern Asian region, the frequencies become lower from south to north, favouring clinality. The Central Asian, Northeast Asian, and Australian samples and to a lesser extent the European sample including the UK series have a much lower incidence of this trait. There is a decisive division between the American Indian, Tibetan/Nepalese/Assam/Sikkim and the Subsaharan African samples and the other regional samples in the world.

On average, the complete type and the incomplete median type are more frequently observed than the other types. The incomplete lateral and incomplete asymmetric types are less frequent, and the incomplete symmetric bipartite type is rare or at least uncommon. The complete type, however, is rarely found in the western Eurasian region.

DISCUSSION

It is often suggested that the incidence of the occipital sutural bones (accessory ossicles) and artificial cranial deformation are highly correlated with each other (Oetteking, 1930; Ossenberg, 1970; Gottlieb, 1978; Lahr, 1996). El-Najjar & Dawson (1977), on the other hand, pointed out that, at the very least, the frequency of occurrence of wormian bones in the lambdoid suture in deformed and undeformed skulls showed no significant difference. According to Ossenberg (1969), however, groups practicing deformation not only have, as a rule, a higher incidence of wormian bones, but in general have a slower rate of suture closure than other people. She pointed out, moreover, that wormian bones are more common in crania with an Inca bone than in those without. The hypothesis that sutural variation including the Inca bone is not under direct genetic control but is a secondary characteristic brought about by 'ontogenetic stress' including artificial cranial deformation (Ossenberg, 1970; Pucciarelli, 1974; Gottlieb, 1978; Konigsberg et al. 1993; Manzi et al. 1996) is not necessarily adequate to account for the distinctive variations within each geographical area as shown in this study.

The frequency distributions of the Inca bone in the major human populations in the World presented in this study are parallel to those summarised by Martin & Saller (1959). Nevertheless, the present findings indicate that a high incidence of this trait is observed in Tibetan/Nepalese and Assam/Sikkim populations, and in Eskimos. Ossenberg (1969) pointed out that among modern peoples frequencies are highest in marginal 'isolates' believed to have retained traits of early ancestral populations who migrated to the periphery due to population pressure in central areas. If this is true, the pattern of distribution in the world may possibly be explained from the viewpoint of random drift by population size, network, isolation, and edge factors rather than some selection pressure including artificial cranial deformation.

As described previously, the variation in frequency

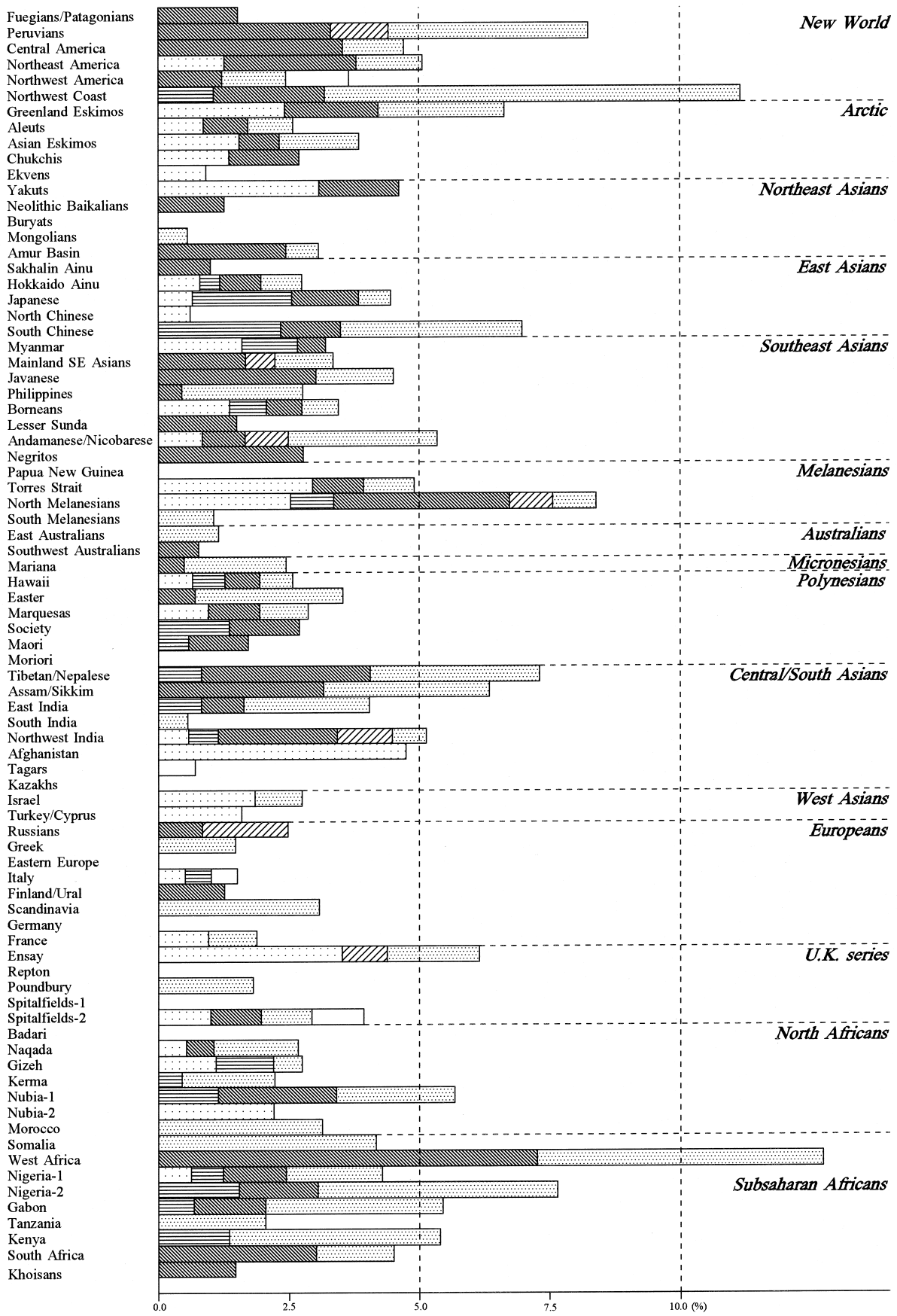

Fig. 8. Graphic display of the frequency variations of the Inca bone for the sex-pooled samples based on the first classification.

Table 3. *Samples classified on the basis of linguistic, ethnological, and geographical background*

Sample name	Samples combined
Eastern Asia	
Northeast Asians	Mongolians, Buryats, Neolithic Baikalians, Yakuts, Amur Basin
Ainu	Hokkaido Ainu, Sakhalin Ainu
East Asians	Japanese, North Chinese, South Chinese
Mainland SE Asians	Myanmar and other mainland Southeast Asians
Island SE Asians	Javanese, Philippines, Borneans, Lesser Sunda, Andamanese/Nicobarese Negritos
Arctic/New World	
Arctic	Ekvens, Chukchis, Aleuts, Asian Eskimos, Greenland Eskimos
North America	Northwest Coast, Northwest America, Northeast America
Central/South America	Central America, Peruvians, Fuegians/Patagonians
Pacific/Oceania	
Micronesians	Mariana
Polynesians	Hawaii, Easter, Marquesas, Society, Maori, Moriori, and other Polynesians (Tonga, Samoa, Cook)
Melanesians	Papua New Guinea, Torres Strait, North Melanesians, South Melanesians
Australians	East Australians, Southwest Australians, and other Australian specimens of locality unknown
Central/South/West Asia	
Tibet/Nepal/NE India	Tibetans, Nepalese, Assam, Sikkim
South Asians	Northeast India, South India, Northwest India, Afghanistan
Central Asians	Tagar, Kazakhs
West Asians	Israel, Turkey/Cyprus
Europe	
Europeans	Russia, Greek, Eastern Europe, Italy, Lapps, Scandinavia, Germany, France
UK	Ensay, Repton, Poundbury, Spitalfields-1, Spitalfields-2
Africa	
North Africans	Gizeh, Badari, Naqada, Kerma, Nubia-1, Nubia-2, Morocco
Subsaharan Africans	Somalia, West Africa, Nigeria-1, Nigeria-2, Gabon, Tanzania, Kenya, South Africa, Khoisans

Table 4. *Frequency distribution of Inca bone based on the 2nd classification of the samples*

Sample name	N	Total	Type I	II	III	IV	V	Others
Eastern Asia								
Northeast Asians	641	0.0156	0.0031	0.0000	0.0094	0.0000	0.0031	0.0000
Ainu	356	0.0225	0.0056	0.0028	0.0084	0.0000	0.0056	0.0000
East Asians	411	0.0341	0.0049	0.0122	0.0073	0.0000	0.0097	0.0000
Mainland SE Asians	367	0.0327	0.0082	0.0054	0.0108	0.0027	0.0054	0.0000
Island SE Asians	718	0.0348	0.0042	0.0014	0.0125	0.0014	0.0153	0.0000
Arctic/New World								
Arctic	596	0.0419	0.0151	0.0000	0.0101	0.0000	0.0168	0.0000
North America	255	0.0706	0.0039	0.0039	0.0196	0.0000	0.0392	0.0039
Central/South America	333	0.0601	0.0000	0.0000	0.0300	0.0060	0.0240	0.0000
Pacific/Oceania								
Micronesians	205	0.0244	0.0000	0.0000	0.0049	0.0000	0.0195	0.0000
Polynesians	773	0.0220	0.0026	0.0039	0.0078	0.0000	0.0078	0.0000
Melanesians	452	0.0354	0.0133	0.0022	0.0111	0.0022	0.0066	0.0000
Australians	276	0.0072	0.0000	0.0000	0.0036	0.0000	0.0036	0.0000
Central/South/West Asia								
Tibet/Nepal/NE India	186	0.0699	0.0000	0.0054	0.0322	0.0000	0.0323	0.0000
South Asians	521	0.0326	0.0058	0.0038	0.0096	0.0019	0.0115	0.0000
Central Asians	219	0.0046	0.0000	0.0000	0.0000	0.0000	0.0000	0.0046
West Asians	172	0.0233	0.0174	0.0000	0.0000	0.0000	0.0058	0.0000
Europe								
Europeans	840	0.0155	0.0036	0.0012	0.0024	0.0024	0.0048	0.0012
UK	688	0.0203	0.0073	0.0000	0.0015	0.0015	0.0087	0.0015
Africa								
North Africans	906	0.0262	0.0066	0.0044	0.0033	0.0000	0.0121	0.0000
Subsaharan Africans	997	0.0502	0.0010	0.0060	0.0150	0.0000	0.0281	0.0000

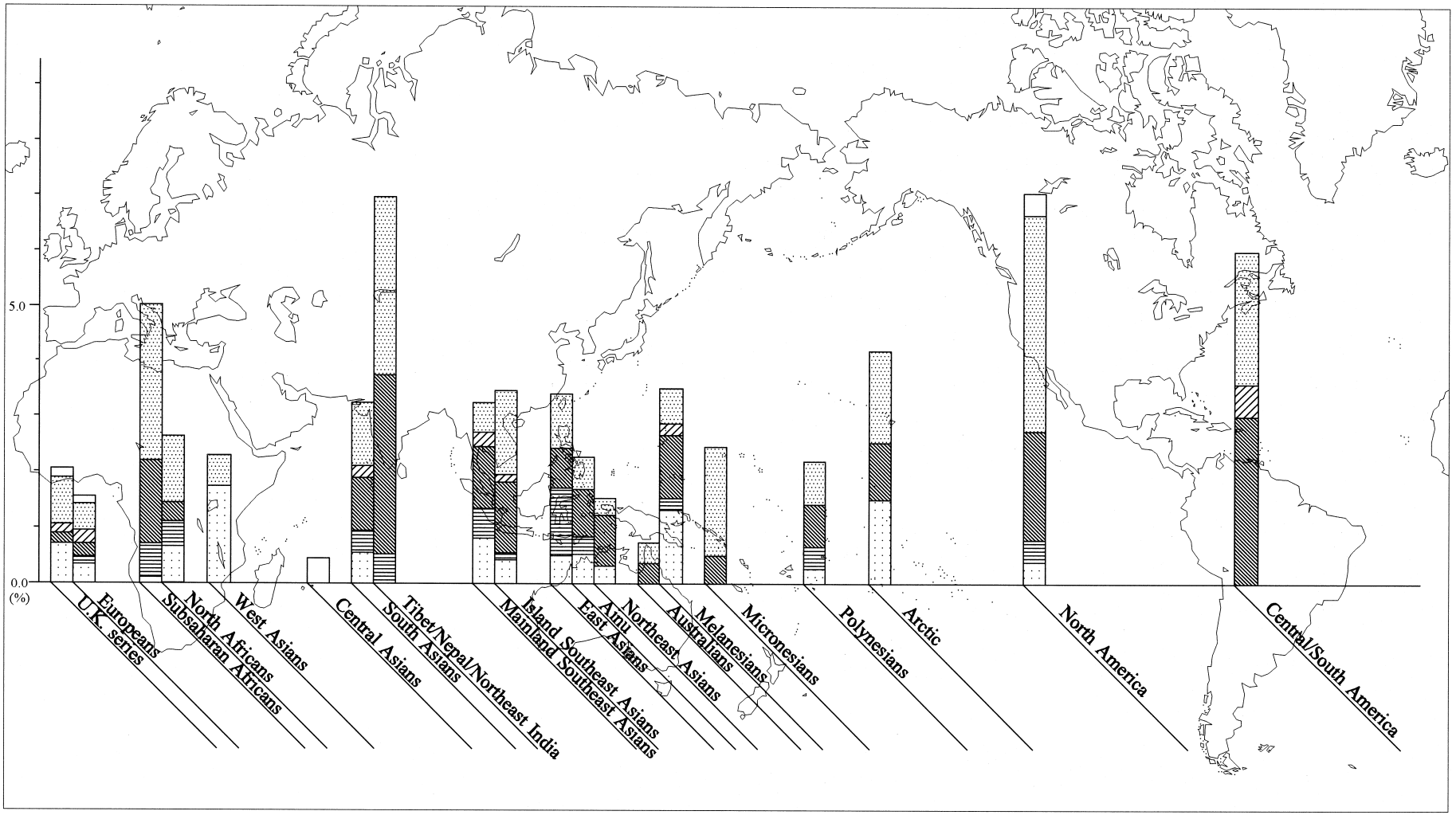

Fig. 9. Variation in frequency of the Inca bone based on the second classification given on the world map.

of the Inca bone indicates that there may be a regional shift within each circumscribed geographical area without any identifiable adaptive value. Taking this finding together with little clinality coincides with environmental factors, subsistence patterns, and life-styles between the large geographical areas into consideration, we cannot completely eliminate the possible genetic background for the occurrence of the Inca bone, as suggested by pedigree studies by Torgersen (1951).

Weidenreich (1939, 1943) and Wu & Wu (1985) regarded the Inca bone as one of the regional characters of East Asians, providing evidence of regional continuity in the evolution of Chinese *Homo erectus* into modern East Asian populations. This classic regional continuity model or polycentric view of modern human emergence has been succeeded and outlined in a broader theoretical context by Wolpoff and his colleagues as the multiregional evolution model (Thorne & Wolpoff, 1981; Wolpoff, 1985, 1989, 1992). An alternative explanation to the origin of anatomically modern humans, the single origin or 'out of Africa' hypothesis, has been proposed from a genetic and palaeoanthropological standpoint (Stringer & Andrews, 1988; Stringer, 1990, 1992; Wilson & Cann, 1992; and many others).

As shown in this study, the incidence of the Inca bone is relatively high in populations of eastern Asian origin such as Arctic Eskimos, American Indians, and Tibetans/Nepalese. However, this trait is not restricted to East Asians and related populations, also occurring in Subsaharan Africans. This indicates that the Inca bone is not a uniquely eastern Asian regional character.

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Appendix. Provenance of materials used

Sample name	Brief information
East Asians	
Japanese	Recent Japanese from Main-Island Japan (Tohoku University)
Hokkaido Ainu	Recent Ainu in Hokkaido, Japan; many of the individuals examined were excavated by Y. Koganei in 1888–1889, but including skulls collected later (University of Tokyo, Sapporo Medical University)
Sakhalin Ainu	Recent Ainu from southern Sakhalin (Museum of Anthropology and Ethnography, Institute of Anthropology of Moscow State University, Kyoto University, Musée de l'Homme)
North Chinese	Northern part of China, mainly from Liaoning Prefecture (University of Tokyo, Kyoto University)
South Chinese	Chinese from south of Cheng Kiang River (Natural History Museum, Musée de l'Homme)

Appendix (*cont.*)

Sample name	Brief information
Southeast Asians	
Myanmar	Recent inhabitants in Burma now called Myanmar (Natural History Museum, University of Cambridge)
Mainland SE Asians	Recent inhabitants in Mainland Southeast Asia, Thai, Vietnam, Laos, Cambodia, and Malay (Natural History Museum, University of Cambridge, Musée de l'Homme)
Javanese	Recent inhabitants of Java including a few samples from Sumatra, Billiton, and Mentawei Islands (Natural History Museum, University of Cambridge, Musée de l'Homme, American Museum of Natural History)
Philippines	Recent native inhabitants of the Philippines, Tagalog, and other tribes from Luzon and Mindanao Islands (Natural History Museum, University of Cambridge, Musée de l'Homme)
Borneans	Native inhabitants in Borneo Island, mainly the so-called land Dayaks, but including Iban (Sea Dayaks) (Natural History Museum, University of Cambridge, Musée de l'Homme)
Lesser Sunda	Recent inhabitants in Lesser Sunda Islands; Timor Bali, Sumbawa, Flores, and Celebes Islands (Natural History Museum,University of Cambridge, Musée de l'Homme, American Museum of Natural History)
Andamanese/ Nicobarese	Recent inhabitants in Great Andaman Island, Jarawa and others (probably Andaman Negritos), including a few samples from Little Andaman Island; recent native people from Nicobar Islands (Natural History Museum, University of Cambridge, Musée de l'Homme)
Negritos	Recent Philippine Negritos, Aeta, Agta, and other tribes (Natural History Museum, Musée de l'Homme, American Museum of Natural History)
Northeast Asians	
Mongolians	Recent people from Mongolia (Musée de l'Homme, National Museum of Natural History, American Museum of Natural History)
Buryats	Recent Buryats from Northeast Siberia (Museum of Anthropology and Ethnography, Musée de l'Homme)
Neolithic Baikalians	Neolithic people from around the Lake Baikal, Northeast Siberia (Museum of Anthropology and Ethnography, Institute of Ethnography and Archaeology, Institute of Anthropology of Moscow State University, Irkutsk State University)
Yakuts	Recent Yakuts from Northeast Siberia (Museum of Anthropology and Ethnography, Institute of Anthropology of Moscow State University, Musée de l'Homme)
Amur Basin	Recent indigenous tribes from Amur River basin and northern Sakhalin; Ulchs, Nanaians, Negidals, Nivkhs, and Orochs (Museum of Anthropology and Ethnography, Institute of Anthropology of Moscow State University, American Museum of Natural History, Natural History Museum)
Arctic	
Ekvens	Iron age people from the Ekven site at the Chukot Peninsula (Institute of Anthropology of Moscow State University)
Chukchis	Recent Chukchis from arctic region of Northeast Siberia (Museum of Anthropology and Ethnography, Institute of Anthropology of Moscow State University, Musée de l'Homme, National Museum of Natural History, American Museum of Natural History)
Aleuts	Recent indigenous people of Aleutian Island chain, Kagamil, Umanak, Shiprock (National Museum of Natural History, American Museum of Natural History)
Asian Eskimos	Eskimos from Arctic region of Northeast Siberia (Museum of Anthropology and Ethnography, Institute of Anthropology of Moscow State University)
Greenland Eskimos	Recent Eskimos from Greenland, including a few specimens from Northeast Canada (Natural History Museum, University of Cambridge, Musée de l'Homme)
New World	
Northwest Coast	Native Americans from Northwest Coast of Canada (Natural History Museum, University of Cambridge)
Northwest America	Native Americans from Plateau, Great Basin, California, and Southwest Cultural areas (Natural History Museum, University of Cambridge, Musée de l'Homme)
Northeast America	Native Americans from Great Plains, Northeast and Southeast Cultural Areas (Natural History Museum, University of Cambridge)
Central America	Native Americans from Mexico, Colombia, Ecuador, Carib, Venezuela, and Guyana (Natural History Museum, University of Cambridge)
Peruvians	Cerro del Oro, Huacho, Pisagua, and other regions (Natural History Museum)
Fuegians/Patagonians	Terra del Fuego and Patagonia region, southernmost part of South America (Natural History Museum, University of Cambridge, Musée de l'Homme)
Micronesians	
Mariana	Recent Chamorros from Guam, Saipan, and Tinian (B.P. Bishop Museum, Musée de l'Homme)
Polynesians	
Hawaii	Recent native Hawaiians; Mainly from Oahu Island (Natural History Museum, University of Cambridge)
Easter	Recent Easter Islanders (Natural History Museum, University of Cambridge, Musée de l'Homme)
Marquesas	Marquesans from Uahuka Island (Natural History Museum, Musée de l'Homme)
Society	Recent Society Islanders, mainly from Tahiti Island (Natural History Museum, Musée de l'Homme)
Maori	Recent aboriginal populations from New Zealand (Natural History Museum, University of Cambridge)
Moriori	Recent aboriginal populations from Chatham Island (Natural History Museum, University of Cambridge)

Appendix (*cont.*)

Sample name	Brief information
Melanesians	
Papua New Guinea	Purari River delta, Fly River delta, Sepik River delta, and other regions (Natural History Museum)
Torres Strait	Recent inhabitants of the Islands of Torres Strait (Natural History Museum, University of Cambridge, Musée de l'Homme)
North Melanesians	Recent indigenous inhabitants from New Ireland, New Britain, Solomon, and Santa Cruz Islands (Natural History Museum, University of Cambridge)
South Melanesians	Recent indigenous inhabitants from Loyalty, New Caledonia, Vanuatu, and Fiji Islands (Natural History Museum, University of Cambridge)
Australian Aborigines	
East Australians	Recent Australians mainly from New South Wales, including a few specimens from Queensland and Victoria (Natural History Museum, University of Cambridge, Musée de l'Homme, American Museum of Natural History)
Southwest Australians	Northern Territory, South Australia, and Western Australia (Natural History Museum, University of Cambridge, Musée de l'Homme American Museum of Natural History)
Central/South Asians	
Tibetan/Nepalese	Natives of Tibet, mainly from Tibetan soldiers in the late 19th century; Sunwar and other region, low land of Nepal (Natural History Museum, University of Cambridge)
Assam/Sikkim	Mishme, Naga, Thado, Kuki, Singho, Lepcha, and other tribes; Darjeeling, Assam and Sikkim district, Northeast India (Natural History Museum)
East India	Bengal and Bihar districts, Hindu people, Musselman from west Bengal district, natives of Patna and other regions of the Province of Bihar, Koa and others from Cuttack, Province of Orissa (Natural History Museum)
South India	Native Indians from around Madras, Province of Tamil Natu, mainly Dravidians; Malabar Coast of India, Province of Karnataka, including Tamil, Southern Part of India (Natural History Museum)
Northwest India	Musselman, Peshwar, Hindu low caste, Mohammedan, Punjab and Kashmir Districts, Northwest India and Pakistan (Natural History Museum)
Afghanistan	Kelati, Pecheen Valley and other regions, native of Afghanistan(Natural History Museum)
Tagars	Iron age Tagar culture from western Siberia (Museum of Anthropology and Ethnography, Institute of Anthropology of Moscow State University)
Kazakhs	Recent Kazakhs from Central Asia (Museum of Anthropology and Ethnography)
West Asians	
Israel	Tell Duweir (Lachisch), Bronze and Iron age, ca. 5,000–3,000 y B.P., Palestine, Israel (Natural History Museum)
Turkey/Cyprus	Hellenistic and Roman Periods of Cyprus and Constantinople, Turkey (Natural History Museum)
Europeans	
Russia	Recent Russians, Don Cossack soldiers Odessa, etc. (Natural History Museum, University of Cambridge, Museum of Anthropology and Ethnography, Institute of Anthropology of Moscow State University)
Greek	Ancient and recent Greece from Sigmeum, Cyrene, Samos, Corfu, Athens, Greek (Natural History Museum)
Eastern Europe	Slav group from Poland, Czechoslovakia, Herzegovina, Bulgaria, and Yugoslavia (Natural History Museum)
Italy	Frosinone, Rome, Sicily, Otaranto, Aburzzo, recent Italian soldiers (Natural History Museum)
Finland/Ural	Saarijarvi, Birkala, Kides, Carelia, Finland; including a few specimens of Ural language speaking people (Natural History Museum, Musée de l'Homme)
Scandinavia	Recent Norwegians; Calacarlians (Kopperberg), Sweden; Stockholm (Natural History Museum, University of Cambridge)
Germany	München, Hessian soldiers, Hostein, Saxon regiment, Leipzig, Germany (Natural History Museum, University of Cambridge)
France	Ouchy, Upnor near Chatham, Lower Brittany, Soldiers in the army of Napoleon, recent French people, France (Natural History Museum, University of Cambridge, Musée de l'Homme)
UK series	
Easay	Late Medieval to post-Medieval periods, Scotland, excavated at Ensay (Natural History Museum)
Repton	St Wystans, Repton, Derbyshire, Northeast region of England, Medieval era (Natural History Museum)
Poundbury	Late Roman period, Poundbury, Southwest England (Natural History Museum)
Spitalfields-1	Mid-Victorian, Christ Church, Spitalfields, eastern region of London, England (Natural History Museum)
Spitalfields-2	Pre-17th century, Spitalfields (University of Cambridge)
North Africans	
Badari	Ancient Egyptians from Badari, ca 5,000–4,000 y B.P., Egypt (University of Cambridge)
Naqada	Predynastic Egypt from Naqada, ca 5,000–4,000 y B.P., Egypt (University of Cambridge)
Gizeh	26th–30th Dynasty, 664 B.C.–343 B.C., Gizeh, Egypt (University of Cambridge)
Kerma	Dinka near Omdurman, Deruish, 12th 13th Dynasty of Nubia, Kerma (University of Cambridge)
Nubia-1	Islands of Hesa and Biga, early Christian or Christian date, Nubia (University of Cambridge)
Nubia-2	Recent population from Nubia (Natural History Museum)

Appendix (*cont.*)

Sample name	Brief information
Subsaharan Africans	
Morocco	Tenerife, Orotaua, Guanche, Canary Islands, Morocco (Natural History Museum)
Somalia	Erigavo district, Ogaden Somali, Darod Kuhar, Burao district, Somalia (University of Cambridge)
West Africa	Recent people from West Africa; Senegal, Gambia, Guinea, Sierra Leone, Liberia, and Ivory Coast (Natural History Museum)
Nigeria-1	Ibo tribe from northern Nigeria, West Africa (Natural History Museum, University of Cambridge)
Nigeria-2	Ashanti tribe from northern Nigeria, west Africa (Natural History Museum, University of Cambridge)
Gabon	Fernand Vaz River, recent people from Gabon (Natural History Museum)
Tanzania	Haya tribe from Musira Island, Lake Victoria, Kikunga and Ikurunga Cave, Tanzania (University of Cambridge, Natural History Museum)
Kenya	Nairobi, Teita Hills, Bantu speaking people Kenya (University of Cambridge, Natural History Museum)
South Africa	Zulu and once called Kaffir tribes, Pietremanitzburg, Natal and other places of South Africa (Natural History Museum, University of Cambridge, American Museum of Natural History)
Khoisan	Recent Bushmans and Hottentots from South Africa (Natural History Museum, University of Cambridge, American Museum of Natural History)

Natural History Museum: London, UK
University of Cambridge: Duckworth Laboratory, Cambridge, UK
Musee de l'Homme: Paris, France
Museum of Anthropology and Ethnography: St Petersburg, Russia
Institute of Ethnography and Archaeology: Novosibirsk, Russia
Institute of Anthropology of Moscow State University: Moscow, Russia
National Museum of Natural History, Smithsonian Institution: Washington, DC, USA
American Museum of Natural History, New York, USA
B.P. Bishop Museum: Honolulu, USA
University of Tokyo: Tokyo, Japan
Sapporo Medical University: Sapporo, Japan
Kyoto University: Kyoto, Japan
Tohoku University: Sendai, Japan